An Integrated Approach to Electronic Navigation

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ABSTRACT

While the Global Positioning System (GPS) is and will continue to be an excellent navigation system, it is neither flawless nor is it the only system employed in the navigation of today's seagoing warfighters. The modern warfighter must operate with dominant maneuverability, precision engagement capability, full-dimensional protection, and focused logistics. To meet these requirements, an integration of independent, self-contained, self-initiated, and externally referenced systems must be realized. The Navigation Sensor System Interface (NAVSSI) AN/SSN-6 (V) provides this capability through the real-time collection, processing, and distribution of accurate and reliable positioning, navigation, and timing (PNT) data from varied shipboard sensors and systems. NAVSSI adds to this an electronic navigation capability that provides the ship navigation team with route planning, route monitoring, and safety of navigation capabilities.

INTRODUCTION

The Navigation Sensor System Interface (NAVSSI) integrates inputs from various shipboard navigation sensor systems, distributes the integrated navigation solution to shipboard users, and provides a dedicated workstation to the ship's navigator. NAVSSI uses an open systems architecture, government off-the-shelf (GOTS) software, and commercial off-the-shelf (COTS) hardware [1].

NAVSSI is an Evolutionary Acquisition (EA) program that is entering its fourth phase: the development of Block 3 hardware and software. The new Block 3 configuration is being developed to expand the number of sensor and user systems supported. Block 3 also incorporates a Global Positioning System (GPS) Joint Program Office approved embedded GPS receiver directly into NAVSSI, refines its integrated navigation solution algorithms, and further expands the navigation tools available to the ship's navigation team.

The NAVSSI system is actually an integration of subsystems. The Real-Time Subsystem (RTS), which collects, processes, and distributes the positioning, navigation, and timing (PNT) data, uses a set of navigation source integration algorithms to blend input data from sensors such as GPS and Inertial Navigation Systems (INS) to produce a highly accurate and robust navigation solution. When required, this solution is referenced to the ownship's reference point (OSRP).

The Display Control Subsystem (DCS) provides the operator interface to the RTS. It also contains the electronic charting and navigation capabilities as well as a radar interface and chart product distribution capability. The charting software used is the U.S. Coast Guard developed Command Display and Control Integrated Navigation System (COMDAC INS). The DCS and COMDAC INS software packages are built on the Defense Information Infrastructure Common Operating Environment (DII COE) and together will enable NAVSSI to lead the way to Electronic Chart Display Information System–Navy (ECDIS–N) compliance.

The DCS can display ownship's navigation sensor information, log navigation fix data, use the navigation toolkit, display digital nautical charts and radar contacts, and control the RTS(s). The RTS accepts and integrates data from both external navigation sensor systems and the embedded GPS receiver cards. The RTS distributes real-time navigation data and precise time to shipboard user systems and communication systems.

The DCS communicates with each RTS via a local-area network (LAN). Depending on the particular installation this may be an independent subsystem LAN or an existing shipboard LAN. Many, but not all, installations of NAVSSI Block 3 will include two RTSs. On a dual RTS installation, two RTSs will exchange data via a reflective memory link.

Other system components are the Bridge Workstation (BWS) and NAVSSI Remote Station (NRS), which are the remote displays for the DCS operator. The NAVSSI BWS and NRS have full control and display capabilities to ship's force on the bridge.

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The following sections describe the requirements for system performance and the operational characteristics of the NAVSSI Block 3 System.

REAL-TIME SUBSYSTEM (RTS)

The NAVSSI RTS receives navigation data from multiple sensors and systems and provides real-time output of an integrated navigation solution to multiple user systems. The NAVSSI RTS(s) accepts and processes data in a variety of formats as listed in Table 1.

Data Integrity Checking

NAVSSI continuously monitors the data inputs from each source listed in Table 1 to ensure data integrity. Integrity checking consists of, but is not limited to, ensuring proper reception of data over the physical medium connecting the source to NAVSSI. Incomplete messages, messages with checksum errors, etc., are processed as identified in the appropriate interface design specification (IDS). As required, NAVSSI posts visible alerts to the operator.

TABLE 1. Summary of Block 3 data inputs.

System	Message Rate (Hz)[Note 1]	Data Received
Redundant RTS	50[Note 2]	All Sensor Data
DCS	Variable	All Sensor Data, Control, Config, Lever Arms, etc.
AN/SPS 73	1	Scanned Radar Images/Contacts
AN/WRN-6 IP	1	PVT, almanac, status
AN/WRN-6 ntds	1	PVT, status
AN/WSN-5 Ch A	4.07	PVT, $speed_w$, performance
AN/WSN-5 Ch B	8.14 or 16.28	PVT, attitude, $speed_w$, performance
AN/WSN-7 GPS/010	4	PVT, attitude, $speed_w$, performance
AN/WSN-7 Superchannel	50[Note 2]	PVT, attitude, rate $speed_w$, performance
BFTT	1	Training Data
Speed $Log_{digital}$	8	$Speed_w$
DMS/FODMS	10[Note 2]	INS, fathometer, wind, propulsion
DSVL	8	$Speed_w$ or $speed_g$
EM Log	Continuous	$Speed_W$
Fluxgate compass	1	Heading
FOAL receiver	Continuous	RF Input
GVRC	1	PVT, status, almanac
Gyrocompass	Continuous	Synchro heading
ICAN	Wind at 10 Std Msg at 50	Wind speed and direction, std msg
IP-1747/WSN-7	0.125	WSN-7 Control
MK 38 AEGIS Clock Converter	1024	Aegis Combat System Time
MK 39 AEGIS Clock Converter	1024	Aegis Combat System Time
Moriah (NDWMIS)	10	True wind speed and direction
SWAN	50	Std msgs
LPD 17 Wind	10	Wind speed and direction
UQN-4/4A	1	$Depth_{keel}$

[Note 1] Data rates are approximate.
[Note 2] Multiple messages, highest rate given.

Message level validity checking is conducted based on source validity indicators transmitted with the data if the appropriate IDS provides for such indicators. Sources indicating that their data are invalid are not used by NAVSSI until the data are again marked valid by the source.

NAVSSI provides navigation data validity monitoring, consisting of continuous monitoring of the time evolution of each position source's error characteristics. If estimates in the source's error consistently fall outside of the source's statistical performance bounds, the source is marked as invalid. The automatic source integration algorithm does not use these data, and NAVSSI posts a visible alert to the operator. If a NAVSSI operator manually selects a source that is out of its performance bounds, NAVSSI displays a warning message to the operator.

Navigation Source Integration

NAVSSI provides navigation source integration algorithms that blend the input data received from GPS with available INS data to produce a highly accurate and robust navigation solution. The algorithms written to perform navigation source integration take into account the error characteristics associated with each navigation sensor system and will meet the accuracy requirements specified in Table 2. Each RTS resolves navigation position information from each sensor to the same single shipboard reference point. The reference point for this integrated solution is the OSRP. User systems receive data based on the integrated OSRP solution, excepting those systems for which the IDS states that the data shall reflect a specific data source reference point.

The navigation source integration algorithms operate automatically or manually.

Automatic Source Selection Mode

In Automatic Mode, the RTS(s) provides navigation data from the data sources selected by the navigation source integration algorithms to the DCS and external user systems. The Automatic Mode is the default mode.

The navigation source integration algorithms estimate the accuracy of the data being output by NAVSSI. This accuracy estimate is based on the known nominal error characteristics of the available sensor systems, a comparison of the available data and the maintenance of long-term sensor accuracy data. Some user systems are sent the accuracy estimation data as part of their data message. For other user systems, these data are used to determine the setting of validity bits.

The source integration algorithms enable NAVSSI to provide appropriately referenced latitude and longitude accurate to within 12 m (two dimensions, one sigma) under non-casualty conditions. This accuracy requirement is significantly more stringent than the current requirements for INSs and is one of the primary drivers for the redesign of the NAVSSI Block 2 source integration routines into source integration routines in Block 3. The accuracy requirement is based on a root-sum-square of all known error components, including the worst-case latency-related error for each of the interfaces.

NAVSSI integrates velocity input from the various sensors to maintain a real-time estimate of accurate velocity. A maximum ship speed of 40 knots is assumed.

The source integration algorithms enable NAVSSI to provide attitude data from the best available attitude source. On ships that have INSs, NAVSSI tracks the accuracy of the INSs and provides the users with attitude data from the chosen INS. As seen in Table 2, attitude latency is critical for many user systems because the error caused by data latency can quickly exceed the error budget. Therefore, for certain user systems, it is necessary to schedule data output messages to coincide with the receipt of fresh data from the appropriate sensor in order to meet the requirements given in Table 2.

Manual Source Selection Mode

The operator can override the automatic source selection algorithms for the data displayed on the DCS and the data sent to external users. The operator is prompted to choose one or all of the following sources: position data source, velocity data source, attitude data source, or time data source.

When in manual override, the data sent to the DCS, the INS, and the other external users are taken from the manually chosen sources for data. If the operator does not manually choose a source for a particular type of data, those data continue to be provided via the navigation source integration algorithms. In addition, the NAVSSI operator can manually override the INS integration algorithms and choose the best INS.

If there is a loss of communication with a manually chosen source or if the data from that source are marked as invalid, the following are performed:

- the RTS(s) sends an alert message to the DCS operator;
- if position data were manually selected, the RTS(s) estimates position from the last valid message from the manually selected source and provides these data to the DCS and/or users;
- if velocity data were manually selected, the RTS(s) marks the velocity data being sent to the DCS and/or user systems as invalid;
- if attitude data were manually selected, the RTS(s) marks the attitude data being sent to the DCS and/or user systems as invalid;
- if the time source was manually selected, the RTS(s) maintains the last offset calculated from the chosen time source and uses the microprocessor clock to continue to update time.

Position Data Referencing

The lever arms to correct navigation data from each sensor system to OSRP are entered into the RTS(s) system configuration files via the DCS by the installing activity. Once entered, these lever arm data are maintained in non-volatile storage as part of the ship's NAVSSI system configuration files so that the RTS(s) automatically performs OSRP corrections. Thus, all user systems receive position data referenced to OSRP unless the IDS for that system interface specifically designates that a particular sensor's uncorrected data be used for the position data for that system.

Lever arm data from the following systems (if installed) are provided to the RTSs so that the RTSs perform the corrections needed to reference all position data to OSRP: GPS antenna No. 1, GPS antenna No. 2, INS No. 1, and INS No. 2.

GPS reset data sent to the ship's Inertial Navigation Systems are referenced to OSRP. This is done in order to make the system work equally well with AN/WRN-6 or the dual antenna GPS Versa Modular European Receiver Card (GVRC).

If attitude data are not available from the INS, NAVSSI uses the following estimates to complete its OSRP lever arm corrections:

· Heading = TAN-1 (VE/VN) for positive Velocity East (VE) and VN
  = 180° + TAN-1 (VE/VN) for negative Velocity North (VN)
  = 360° + TAN-1 (VE/VN) for negative VE and positive VN

· Roll = 0°

· Pitch = 0°

INS Accuracy Estimation

In most of the Block 3 configurations, NAVSSI communicates with an installed INS. Depending on the installation, this INS can be the Standard Shipboard Inertial Navigation System (AN/WSN-5) or the Ring Laser Gyro Navigator (RLGN or AN/WSN-7).

Each RTS normally communicates directly with only one INS, but will have access to the data from the other INS in dual RTS/INS installations via a reflective memory link with the second RTS. In support of the sensor integration algorithms and as an aid to the ship's navigation team, each RTS independently and continuously evaluates the accuracy of both INSs. This independent assessment of INS accuracy uses GPS data (when available) and enables NAVSSI to estimate INS accuracy both in terms of absolute accuracy and accuracy relative to the other INS. Thus, these routines enable NAVSSI to choose INS data from the more accurate INS. However, the accuracy algorithms will include a minimum 10% allowance for hysteresis. This will prevent NAVSSI from repeatedly switching back and forth between the two INSs when both have relatively similar performance characteristics. These accuracy estimation routines are a significant improvement over the Block 2 INS assessment algorithms, which simply used the accuracy bits provided by each INS and did not attempt to make any independent assessment of INS accuracy.

The RTS(s) can receive and respond to a manual selection of best INS from the DCS.

Estimated Position Processing

The RTS(s) calculates Estimated Position (EP) based on discrete position fixes, best available heading source, and best available speed source. The RTS(s) can also use manually entered course and speed to calculate EP. EP data are provided to the source integration algorithms for consideration as a candidate for source integration and to the DCS for display. However, EP is not used as source data unless manually selected or as the result of multiple sensor failures.

RTS Output Data

The NAVSSI RTS outputs navigation and time data in a variety of formats. Table 2 summarizes the data output requirements and lists interface criticality requirements for maintaining communications in the event of single and multiple point failures.

Output Data Time Tagging

Time information within output data messages is accurate to within 200 msec (two sigma) root-sum-squared with any timing inaccuracy of the sensor data when the output message structure provides sufficient resolution to support this accuracy. In case of a loss of GPS input, NAVSSI is able to maintain time accurate to 1 msec for 1 day and accurate to 10 msec for 14 days.

Precise Time Distribution

The NAVSSI RTS(s) provides accurate time to user systems by means of Have-Quick, Binary Coded Decimal (BCD) time code, Inter-Range Instrumentation Group (IRIG-B) time codes, 1 pulse per second (1 PPS), and 10 pulse per second (10 PPS). The Have-Quick, BCD time code, and 1-PPS signals meet the standards specified in ICD-GPS-060. The IRIG-B time conforms to the standards set forth in IRIG Standard 200-98. The 10-PPS signal, implemented in the NAVSSI Precise Time Unit has all of the characteristics of the 1 PPS signal except that it is at 10 times the rate. Table 2 identifies the accuracy of the time data required by the various user systems. All requirements are in terms of a two-sigma level of accuracy.

TABLE 2. Block 3 data output summary.

System	Message Rate (Hertz)	Position Accuracy (meters)	Attitude Latency (msec)	Time Accuracy (msec)
ACDS Block 0	8	100	0	100
KSQ-1	1	100	N/A	1000
SMQ-11	50	10	20	1000
SPS-73	4 or 1	16	N/A	100
SQS-53d	1	100	N/A	100
SRC-54 Singars	1	N/A	N/A	1
TPX-42	8	10	50	100
WRN-6	4	N/A	100	N/A
WSN-5	1	100	N/A	1
WSN-7	1	100	N/A	1
ATWCS	Multiple	N/A	N/A	N/A
BFTT	1	0	1000	0.1
BGPHES	1	100	N/A	N/A
CADRT	1	N/A	N/A	N/A
CEC	50 [Note 1]	20	10	0.001
CDL-N	8	100	60	100
COBLU	1	100	N/A	N/A
Combat DF	1	100	N/A	N/A
DCS	1	N/A	N/A	N/A
DBB	1	100	N/A	1000
DSVL	8	N/A	250	125
ERGM	1	20	N/A	10

(Table 2 is continued on the following page.)

[Note 1] Multiple messages, highest rate given.

Output NAVSSI Standard Messages

NAVSSI Standard Messages have been created to facilitate future design efforts for use of a wide variety of potential user systems. The Standard Message content is independent of the hardware chosen for any particular interface, allowing this message to be sent at different rates and over a wide variety of point-to-point and LAN interfaces. NAVSSI Navigation Message is a generic sub-message format designed to meet the requirements of various navigation user systems. It includes basic navigation data and time data. Other sub-messages include True Wind, Apparent Wind, Magnetic Variation, Own-Ship Distance, and Navigation Sensor.

Expansion Port Capability

NAVSSI Block 3 has the capability of supporting at least six new users without any software or hardware system modifications. To meet this goal, each Block 3 RTS hardware suite is designed with expansion ports, of which at least two output ports will be Electronic Industries Association (EIA) Standard RS-422 and at least two ports will be MIL-STD-1397 Rev C Type E (Low Level Serial). Electronic cards supporting the expansion ports need not be actually installed, but the internal cabling and backplate connectors do need to be fully prepared. NAVSSI Expansion Ports transmit one of three messages: the accuracy of the data are 25 m for position, 100 msec for time, and 100 msec for attitude latency. For RS-422 interface, the transmission rate is selectable between 1 or 4 Hz. For NTDS-E interface, the transmission rate is selectable as 1, 4, 8, 16, or 50 Hz. The WRN-6 IP message (or Time Mark Data Message), defined in ICD-GPS-150, has a C4 criticality. The accuracy of the data for position is 25 m and 1 sec for time. The data are transmitted at a rate of 1 Hz over RS-422 interface. The NMEA 0183 message, defined in National Marine Electronics Association (NMEA) 0183 Version 2.30, has a C4 criticality. The message, composed of 10 sub-messages, is transmitted at a rate of 1 Hz, with the exception of Heading True (HDT) at 8 Hz. The accuracy of the data is 100 m for position and 1 sec for time.

TABLE 2. Block 3 data output summary (continued).

System	Message Rate (Hertz)	Position Accuracy (meters)	Attitude Latency (msec)	Time Accuracy (msec)
Exp Port	Note 2	25	100	100
FODMS (Stanag)	40	N/A	N/A	N/A
FODMS (RS 422)	1	100	N/A	N/A
ICAN	50 [Note 1]	20	10	10
IP-1747 WSN-7	0.125 [Note 1]	N/A	N/A	N/A
MK-34 MK-160	8 [Note 1]	20	N/A	10
MK-86	1	20	N/A	100
METOC	1	16	100	N/A
Ndwmis	1 [Note 1]	16	100	N/A
NDDN	1	100	N/A	N/A
NMEA	1	100	100	100
Outboard	Synchro	100	N/A	N/A
SDMS	8	1000	60	1000
SSDS	50 [Note 1]	20	10	10
SWAN	50 [Note 1]	20	10	10
TCS	8	20	10	10
TDBM	1	100	N/A	1000
TRD-F	1	100	N/A	N/A
WSC-3	1	N/A	N/A	N/A

Note 1 Multiple messages, highest rate given.
Note 2 Rate is manually selectable as 1, 8, 16, or 50 Hz.

DISPLAY AND CONTROL SUBSYSTEM (DCS)

The NAVSSI DCS Sensor Data Segment (SDS) and U.S. Coast Guard Integrated Navigation Segment (COMDAC-INS) CSCIs provide the integrated human–computer interface (HCI) for the NAVSSI program. The HCI is available from both the DCS workstation console and the NRS.

The DCS provides NAVSSI operator, ship's navigator, and navigation watch team with tools to plan, monitor, and carry out ownship's navigation; the capability to access and display digital nautical charts (DNCs); the capability to control and monitor RTS operations; a display of navigation sensor data; the capability to record and retrieve navigation information; and the capability to serve as the display and control unit for the GVRC installed in each RTS.

COMDAC-INS is integrated with the DCS SDS to provide a full set of automated navigation tools to the operator. The Joint Mapping Toolkit (JMTK) utilities provided with the DII COE provide the required chart manipulation functions. In combination, NAVSSI's CSCIs provide a navigation system in compliance with U.S. Navy policies and procedures for vessel navigation.

DCS Input from the RTS(s)

The DCS can input data from the RTS(s) via the NAVSSI LAN. The NAVSSI LAN is either the existing shipboard Fiber Data Distributed Interface (FDDI) LAN or a dedicated NAVSSI FDDI LAN. Input data includes external interface communication status, navigation sensor data, alarm, alert, and warning messages from the RTS(s). Input errors and out-of-tolerance conditions are displayed at the DCS and NRS.

Input from the Workstations

The DCS accepts manually input data from the DCS workstation and the NRS. The DCS provides displays to facilitate the manual input of system configuration data including the hardware suite designation and the sensor and user interfaces installed on that particular ship. This includes system configuration data, OSRP and lever arm data, and input of position fixes, course, and speed.

Digital Nautical Chart Access

The DCS HCI is capable of accessing and displaying any of the DNCs produced by the National Imagery Mapping Agency (NIMA) in a convenient and timely manner in accordance with U.S. Navy navigation policy.

Navigation Sensor Data Displays

The DCS provides the NAVSSI operator with the ability to view the most recent navigation data for each of the available sensors such as INSs, GPS receivers, speed logs, depth sensors, wind sensors, manually entered position, course, and speed.

Depending on the particular type of navigation sensor, the data to be displayed includes some subset of the following: time, latitude, longitude, velocity north, velocity east, total velocity (speed over ground), course over ground (COG), ship's heading, attitude data, estimated position (EP), fathometer depth data, magnetic bearing data, true and relative wind speed and direction, source selection algorithm status, interface status, true bearings, radar ranges, and lines of position.

NAVSSI Navigation Status Displays

The DCS provides continuously displayed navigation status lines. The navigation status lines are updated whenever the displayed values change up to a maximum rate of once per second. The data displayed on the status display lines include lines for the following: universal time coordinated (UTC), latitude, longitude, COG, speed over ground (SOG), soundings, data recording status, system alert status, system alarm status, navigation source selection mode (automatic or manual), and INS fix source selection mode.

User Interface Status Display

The DCS generates a display for simultaneous monitoring of the status of each sensor and user interface. The display lists each sensor and user interface and indicates whether that interface is active, i.e., ENABLED or DISABLED. For sensor interfaces, the display also shows whether or not that sensor is a current source for navigation data and whether its selection as a data source is automatic or manual. For user interfaces, the display shows the data source it is receiving and whether that data source was selected automatically or manually.

Navigation History Displays

The DCS can display navigation history data logs for the preceding 24 hours at UTC rollover each day. The data logs are as follows: position and depth provided by NAVSSI, position and depth provided by external users, ship's distance, source selections, GPS fix data from antenna No. 1 and from antenna No. 2 (if installed), fix data applied to INSs (if installed), manually entered fix data, courses and speeds, NAVSSI system crash data, alerts and alarms, and accumulated ownship distance.

DCS Controls

The DCS operator can control all the functions carried out by NAVSSI using graphical user interface (GUI)-based HCI control functions.

Navigation Source Selection Control

The DCS enables the NAVSSI operator to select an operating mode for the navigation source selection algorithms of "Automatic" or "Manual."

INS Fix Source Selection Control

The DCS enables the NAVSSI operator to choose what sensor NAVSSI will use to provide data to the ship's INSs (AN/WSN-5s or AN/WSN-7s).

RTS Expansion Port Controls

In addition to the standard control functions that the DCS performs for all RTS interfaces, the DCS provides the capability to rename expansion ports. Once renamed, the DCS uses the new name in all windows that include the expansion ports.

Time Source Selection Controls

The DCS enables the NAVSSI operator to select a source of time for the RTSs and it provides an actual time for the RTSs to correct to. There are two modes of time source selection: "Automatic" or "Manual." The default mode is the Automatic Mode.

The RTS does not select the time source if that time source does not meet the criteria checklist. The RTS continues to use whatever time source it had been using, whether it had been chosen manually or automatically. The RTS provides an alert to the DCS to advise the user that the chosen source was unacceptable. Faults and failures with the precise time distribution shall be reported to the DCS as alerts.

Navigation History Data Logging

The DCS records the following time tagged navigation history data collected during the preceding 24 hours to non-volatile storage: position and depth as indicated at the DCS (0.1-Hz rate); position and depth provided to external users (1-Hz rate); ship distance; source selection history; GPS fix data from antenna No. 1 and from antenna No. 2 (if installed) (1-Hz rate); fix data applied as input to the INSs; manually entered fix data; courses and speeds; and NAVSSI alerts and alarms.

All data except the 0.1-Hz DCS position and depth file are maintained for a minimum of 24 hours before being overwritten. The 0.1-Hz DCS position and depth data are maintained for at least 45 days before being overwritten.

Data to Tactical Database Manager

The DCS provides navigation data to the shipboard Tactical Database Manager (TDBM) at a user-selectable rate. The TDBM Application Programming Interface (API) calls are used by the DCS to provide these data to the track database via the FDDI LAN.

Supply Almanac Data to TAMPS

The DCS can provide GPS almanac data to the Tactical Air Mission Planning System (TAMPS). The DCS can transmit the almanac files to TAMPS via the LAN. In addition, the DCS can save the data to a 3.5-inch floppy diskette for direct use by TAMPS.

Digital Mapping, Charting, and Geodesy (MCG) Product Serving

NAVSSI can serve NIMA digital MCG products to DII COE shipboard user systems via local network connections. NAVSSI can also provide these digital products to non-DII COE clients by providing raw data via Network File System (NFS) and will provide User Datagram Protocol (UDP) broadcasts to notify users of updates that have been made by the operator.

GVRC Controls and Displays

The DCS serves as the control and display unit for the GVRCs.

COMDAC–INS

The U.S. Navy and Coast Guard implemented a joint development effort for chart display and manipulation called Command Display and Control–Integrated Navigation Segment (COMDAC-INS). COMDAC–INS is a DII segment that serves as the charting segment in the NAVSSI Block 3 DCS as defined in the NAVSSI-B3-IRS-101. The DCS HCI is developed under the DII COE architecture to work with the COMDAC–INS in providing the capabilities described in the following sections.

ECDIS-N and DoD Interoperability Requirements

The COMDAC–INS is designed in accordance with the guidelines and performance standards outlined in the ECDIS-N Policy Letter [2]. It accepts inputs from Navy standard automated and continuous positioning systems. The COMDAC–INS will accept radar and visual navigation fix information.

Display Requirements

The COMDAC–INS is designed to display all system digital nautical chart (SDNC) information, which is subdivided into three categories: standard display, display base, and all other information. When a chart is first displayed, it provides the standard display at the largest scale available.

The system will display DNC information and updates without degradation of their information content once the chart update format is determined by NIMA. A "north-up" orientation is required, with others permitted. The system uses recommended International Hydrographic Organization

(IHO) colors provided by NIMA symbology set (GEOSYM) and is visible in both day and night conditions. The system can display SDNC information for route planning, monitoring, and supplementary navigation tasks.

Display of Other Navigational Information

Radar and other navigational information may be added to the COMDAC–INS display. The system is designed not to degrade the SDNC information and to remain clearly distinguishable from the SDNC information.

Route Planning

The system can carry out route planning in a simple and reliable manner. It provides for route planning (including straight and curved segments) and route adjustment (e.g., adding, deleting, or changing the position of waypoints to a route). It is possible to plan an alternative route in addition to the selected route. The selected route is clearly distinguishable from the other routes. The mariner can specify a limit of deviation from the planned route. An automatic off-track alarm when deviating from a planned route by the limit specified is provided. An indication is provided if the mariner plans a route across an own ship's safety contour or the boundary of a prohibited area or of a geographical area for which special conditions exist.

Route Monitoring

The system can carry out route monitoring in a simple and reliable manner. For route monitoring, the selected route and ownship's position normally appear whenever the display covers that area. It is also possible to display a sea area that does not have the ship on the display (e.g., for look ahead, route planning). If this is done on the display in use for route monitoring, the automatic route monitoring functions are continuous (e.g., updating ship's position, providing alarms and indications). It is possible to return immediately to the route monitoring display covering ownship's position by single operator action.

The system provides an alarm within a specified time set by the mariner if the ship is going to cross the safety contour. It provides an alarm or indication if the ship is going to cross the boundary of a prohibited area or of a geographical area for which special conditions exist. An alarm is given when the specified limit for deviation from the planned route is exceeded. The system provides an indication when the input from the position-fixing system is lost, and it also repeats, but only as an indication, any alarm or indication passed to it from a position-fixing system. An alarm is given if the ship is going to reach a critical point on the planned route within a specified time or distance set by the mariner.

The system continuously plots the ship's position. It provides for the display of an alternative route in addition to the selected route. The selected route is clearly distinguishable from the other routes.

The system displays time-labels along the ship's track and other symbols required for navigation purposes such as the following: own-ship past track with time marks for both primary and secondary track; vector for course and speed made good; variable range marker and/or electronic bearing line; cursor; event posting for both DR position and time and EP and time; fix and time; position line time; transferred position line and time for both the predicted and actual tidal stream or current vector with effective time and strength (in box); danger highlight; clearing line; planned course and speed to make good; waypoint; distance to run; planned position with date and time; visual limits of lights arc to show rising/dipping; and position and time of "wheelover."

Voyage Recording

The system can reproduce certain minimum elements required to reconstruct the navigation history and verify the official database used during the previous 12 hours. The system records the complete track for the entire voyage at intervals not exceeding 4 hours. These data are protected and it is not possible to manipulate or change the recorded information.

STELLA

Another program integrated into the NAVSSI DCS is the System to Estimate Latitude and Longitude Astronomically (STELLA). STELLA is a software module developed to provide an integrated set of planning and reduction tools for celestial navigation. STELLA consists of the NAVSSI GUI and a U.S. Naval Observatory (USNO)-developed computational engine (CE). The GUI accepts input data and user commands, calls the CE function to process data, and displays the returned data in text, table, or graphics forms. The CE performs all necessary astronomical and navigational functions.

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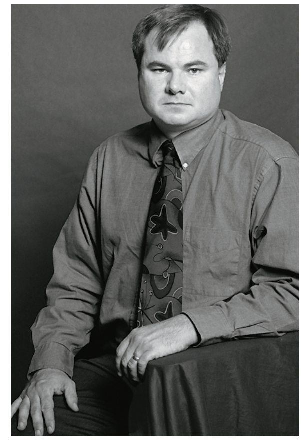

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